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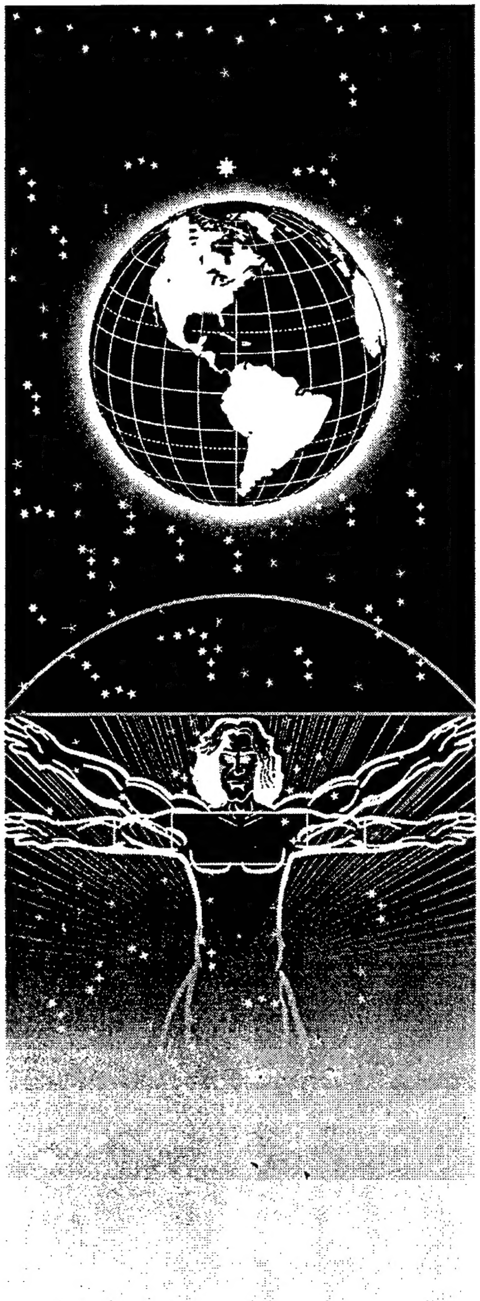

UNITED STATES AIR FORCE RESEARCH LABORATORY

UNMANNED AERIAL VEHICLE OPERATOR QUALIFICATIONS

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March 2000

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This report has been reviewed and is approved for publication.

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There are large differences in operator qualifications for unmanned aerial vehicles (UAVs) operated by the Department of Defense. These differences were examined to identify underlying causes. For tactical UAVs operated by the US Navy, Marine Corps, and Army, specially trained enlisted personnel may qualify as internal pilot. Flight experience in manned aircraft is not required. For the medium-altitude endurance UAV employed by the USAF, only officers who are pilots of manned aircraft or navigators holding a commercial pilot's license with an instrument rating may qualify as internal pilot. The interaction of UAV flight capabilities and federal aviation guidelines underlie these differences. Although service policy and federal aviation guidelines determine operator qualifications, research into the essential skills of UAV operators is needed. Knowledge of essential skills would guide design of training and identify human performance issues associated with mission execution. Knowledge of essential skills will serve as the frame of reference for research into the performance effects of mission length, night-time operations, and circadian dysrythmia. Development of remedial training and cueing technologies could follow as strategies for minimizing adverse effects on mission performance.

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PREFACE

This effort was conducted by the Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Training Research Division (AFRL/HEA) under Work Unit 2313-HA-05, Unmanned Aerial Vehicle Training Research. Work Unit Monitor was Dr Elizabeth L. Martin; Laboratory Task Scientist was Dr Joseph L. Weeks. The requirement for the study issued from Headquarters Air Combat Command (HQ ACC/DRU).

Members of AFRL/HEA (Dr Joe Weeks and Dr Elizabeth Martin) would like to thank MGen Sharpe (ACC/DO) for the privilege of conducting this research. In addition, we want to acknowledge the assistance provided by individuals who facilitated the collection of information presented in this report. These individuals include Mr Stan Baker (ACC/DRU), Lt Col Gary Warner, Commanding Officer, Marine Unmanned Aerial Vehicle Squadron 1, USMC; Lt Cdr D.J. Seagle and Lt Cdr Carol Dolan, V-6 Det, USN; SFC Allen Ruggles, Assistant TRADOC Systems Manager, Unmanned Aerial Vehicles, USA Intelligence Center; SFC Ronald Miller, Joint Unmanned Aerial Vehicle Training Center; Mr Robert Smith, SAIC; Mr Mike Munski, Mr Vance Greenway, and Mr Bruce Lancaster, Teledyne Ryan Aeronautics (TRA); Mr Stewart Moffatt, British Defence Staff Washington, British Embassy; and Maj Jeff Price, HQ Directorate of Royal Artillery, SO2 Unmanned Aerial Vehicle Trials.

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UNMANNED AERIAL VEHICLE OPERATOR QUALIFICATIONS

SUMMARY

Since the early development of unmanned aerial vehicles (UAVs), qualifications for operators have been subject to controversy. Today, the controversy is sustained by differences in qualifications across services. A study was conducted to provide baseline information concerning UAV operator qualifications and to identify reasons for the differences. The study included the Navy (USN) and Marine Corps (USMC) Pioneer, the Army (USA) Hunter, the Air Force (USAF) Predator and Global Hawk, and the British Army Phoenix. Requirements for this diverse set of UAVs present a valuable frame of reference for investigating operator qualifications. Comparisons of requirements reveal large differences in qualifications for the same operator position. Qualifications for mission commander differ across UAVs. For the USN and USMC Pioneer, candidates for mission commander must be aviation officers. For the USAF Predator, candidates for mission commander must be officers. For the Global Hawk, subject-matter experts recommend an officer as mission commander. The USA Hunter and British Army Phoenix stand out as the only UAVs for which a noncommissioned officer (NCO) can qualify as mission commander. These differences issue from UAV flight capabilities and service-unique adaptations of UAV technology. Although NCOs have performed successfully as mission commanders, a compelling argument for officers in this role relates to adaptation of new technology. Historical analyses have revealed that officer participation is a critical requirement for adaptation of new technology because they are in the position to influence doctrine and policy related to the technology. In addition to differences in qualifications for mission commander, there are large differences in qualifications for internal pilot. Enlisted personnel can qualify as internal pilot for the Pioneer and Hunter. Flight experience in manned aircraft is not required. For the Predator, only officers who are pilots or navigators holding a commercial pilot's license with an instrument rating can qualify as internal pilot. Subject-matter experts for the Global Hawk recommend that the internal pilot be a pilot of a manned aircraft with an instrument rating. These differences are due to the interaction of UAV flight capabilities and federal aviation guidelines. The Federal Aviation Administration has designated UAVs as aircraft. As a result, the internal pilot must be rated for the class of airspace in which the UAV operates. The Pioneer and Hunter operate at lower altitudes and closer to the internal pilot allowing flight in restricted airspace where an instrument-rated pilot is not required. The Predator and Global Hawk are designed to operate at extremely high altitudes and at great distances from the internal pilot. To exploit the capabilities of the Predator and Global Hawk, flight in Class A airspace is routinely necessary and vehicle operators must be pilots of manned aircraft who hold an instrument rating. Although federal aviation guidelines support USAF policy concerning operator qualifications for the Predator, the argument that UAV operator qualifications are driven by policy will not end the controversy. Recommend research into the essential skills of UAV operators to introduce an empirical frame of reference for evaluating operator qualifications and to support successful adaptation of UAV technology.

UNMANNED AERIAL VEHICLE OPERATOR QUALIFICATIONS

INTRODUCTION

The Joint Doctrine Encyclopedia (1997) defines unmanned aerial vehicle (UAV) as a powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload. Ballistic or semi-ballistic vehicles, cruise missiles, and artillery projectiles are not considered unmanned vehicles. UAVs are intended to complement other reconnaissance systems, providing an additional capability for the commander to conduct reconnaissance, surveillance, and target acquisition (RSTA) particularly for missions that would be high risk for manned systems or when satellite reconnaissance is not immediately available. They are alternately described as unmanned aerial vehicles, uninhabited aerial vehicles, remotely piloted vehicles, and remotely operated aircraft.

Unmanned aerial vehicles are one element of an apparent military technical revolution. According to Krepinevich (1992), a military technical revolution occurs when the application of new technologies in military systems combines with innovative operational concepts and organizational adaptation to fundamentally alter military operations. Krepinevich suggests three areas of technology progression may be laying the foundation for a military technical revolution. First, there is the advent of systems for performing reconnaissance, surveillance, tracking, and engagement functions at greatly extended ranges. Second, there is the development of long-range, conventional, precision-guided munitions. Third, technology advances may provide the means of integrating information systems with extended-range, precision-guided munitions. These developments could merge to form a capability to rapidly acquire, process, and disseminate surveillance and targeting information for the purpose of engaging targets at extended ranges with a high degree of accuracy. It will involve the use of space platforms, UAVs, high-speed computers, and sensors to gather, process, and disseminate information.

Since the early development of UAVs, operator qualifications have been subject to controversy. Kiggans (1975) states,

> **"The qualifications and status of remotely piloted vehicle operators are among the most controversial aspects of remotely piloted vehicle development...Opinions about who should be future ... operators range anywhere from the man off the street to a highly qualified pilot with engineering background."**

Today, the controversy is fueled by differences across the military services in operator qualifications. Air Force policy requires that UAV operators be pilots of a fixed-wing aircraft or a navigators holding a Federal Aviation Administration (FAA) commercial pilot's license with an instrument rating (Air Combat Command Syllabus,

RQ-1 Air Vehicle Operator Basic Training, Course RQ100BQRPN, February, 1998). This policy was originally implemented at a time of high operations tempo when pilots were in great demand and when the available pool of pilots was diminishing due to low retention. Currently USAF-wide there are 855 fewer pilots than needed and it is projected that there will be 2,000 fewer than needed by the year 2002 (Zuegel, 1999). Given these pressures, the requirement for pilots to be UAV operators was disputed. It was pointed out that the Navy, Marine Corps, and Army employ enlisted personnel as UAV operators. Because large differences in operator qualifications were believed to exist, this study was commissioned to ascertain UAV operator qualifications and to identify reasons for differences. To begin, it was necessary to identify UAVs to include in the study.

Wagner (1982) describes important highlights in the history of UAVs including capabilities developed by the USAF and Ryan Aeronautical Company during and after the Vietnam War. During this period, it was demonstrated that UAVs could be used for reconnaissance, surveillance, target acquisition, and strike. Since that time, many different types of UAVs have been developed and many are being developed. They vary from hand-held, micro-UAVs to those similar to commercial jets. Because of this diversity, a UAV taxonomy was needed to guide the focus of the study. Draft Joint Publication 3-55.1, Joint Tactics, Techniques, and Procedures for Unmanned Aerial Vehicles, dated December 1998, provides such a taxonomy. Although this draft joint publication is not an authoritative or official source for joint doctrine, it provides useful general information concerning categories of UAVs. Two major classes, tactical and endurance, are described.

The first major class, tactical UAVs, are designed, equipped, and operated to support tactical units with local area and battlefield intelligence that support their operations. The primary mission of tactical UAV units is to support their respective service component commands as a tactical RSTA system providing the commander a capability to gather near-real-time (NRT) data in support of missions throughout the range of operations from peace to war. Tactical UAVs may support the joint force commander or geographical commander by aerial reconnaissance, intelligence preparation of the battle space, warning, targeting, and battle damage assessment (BDA). There are three subclasses of tactical UAVs. Vertical takeoff and landing tactical UAVs (VTOL-TUAV) represent a future capability for the naval services. This subclass includes UAVs that will be employed from ship and used for RSTA in support of both surface and airborne weapon systems. VTOL-TUAVs are designed to have an operational radius of approximately 100 nm. The second subclass, close-range tactical UAVs (CR-TUAVs), are designed to provide RSTA and BDA mission support to commanders of brigades, armored cavalry regiments, and light divisions. CR-TUAVs are designed to have an operational radius of 30 to 50 nm. The third subclass, short-range tactical UAVs (SR-TUAVs), typically provide RSTA to commanders at the corps level and at echelons above corps level. SR-TUAVs have a maximum altitude of 15,000 ft and an operational radius of approximately 100 nm with relay data links. Examples of SR-TUAVs are the Pioneer used by the US Navy (USN) and US Marine Corps (USMC), and the Hunter used by the US Army (USA).

The second major class, endurance UAVs, are designed, equipped, and operated to support joint task force commanders and theater/national command and control nodes with long-range, long-dwell, NRT theater-level and tactical intelligence. The primary mission of endurance UAVs is to support the geographic combatant commander or subordinate joint forces commander. There are two subclasses of endurance UAVs. Medium-altitude endurance (MAE) UAVs are designed to provide near continuous, on-station coverage with a maximum altitude of 25,000 ft and an operational radius of approximately 400 nm. The second subclass, high-altitude endurance (HAE) UAVs, represents a future capability. The HAE-UAV is designed for sustained, high-altitude surveillance and reconnaissance with a projected maximum endurance over 40 hours, a maximum altitude of more than 50,000 ft, and maximum operational radius in excess of 3,000 nm.

The taxonomy of UAVs identified in draft Joint Publication 3-55.1 was a key reference in selecting UAVs. Because operator qualifications for the USAF Predator were of primary interest, similarity to the Predator was an important consideration in determining which UAVs to include in the study. Similarity was determined on the basis of maximum flight capabilities. This criterion was adopted because maximum flight rather than typical flight determines minimum operator qualifications. This approach resulted in exclusion of micro, close-range, and VTOL UAVs because their flight capabilities are significantly less than that of the Predator. Short-range tactical UAVs were included because these UAVs have flight capabilities more similar to the Predator and represent the UAVs that are of the greatest interest relative to the controversy over operator qualifications.

OBJECTIVE

The objective was to describe qualification and training requirements for operators of UAVs used by the Department of Defense and other nations. This involved obtaining information concerning UAV mission, crew composition, occupational structure, crewmember duties, and qualifications. Also, information concerning approaches to training and training course lengths was obtained. Although qualification and training requirements would be obtained for all crewmember positions, the primary emphasis would be on vehicle controller. The general term "operators" includes vehicle controllers, sensor operators, mission planners and mission commander. Specific crewmember titles are specified where appropriate. The USN and USMC Pioneer and USA Hunter represent the subclass of SR-TUAVs. The USAF Predator represents the subclass of MAE-UAVs and the Global Hawk represents the subclass of HAE-UAVs. The British Army Phoenix is included as an example of another nation's UAV capability.

APPROACH

Information was obtained by telephone interviews and on-site interviews of military, government, and industry subject-matter experts. For currently operational UAVs, qualification and training requirements were available from service regulations. For UAVs being developed, requirements have not been formally established. Therefore,

this report documents recommendations from flight engineers and vehicle operators participating in system development. Qualification and training requirements for the British Army Phoenix were obtained from the British Army, Royal Artillery, UAV Trials Office.

RESULTS

Short-Range, Tactical UAV: Pioneer (USN)

Mission. The mission of the USN Pioneer is to provide day-and-night NRT RSTA, BDA, maritime interception operations, and battlefield management in support of the Carrier Battle Group and Marine Expeditionary Force. It is the only UAV that employs from ship. It has a maximum altitude of 15,000 ft, an operational radius of approximately 100 nm, and approximate endurance of 5 hours.

Crew Composition/Roles. An external pilot (EP) controls the vehicle during launch and recovery from outside of the Ground Control Station (GCS). An internal pilot (IP) controls the vehicle from inside the GCS during ingress, loiter, mission execution, and egress. The EP controls the vehicle through an interface similar to radio-controlled model airplane (RCMA) flight sticks during launch/climb and descent/recovery. The IP typically monitors the autopilot but has limited vehicle control through flight sticks, with autopilot support, during ingress, loiter, mission execution, and egress. The payload operator (PO) controls electro-optical (EO) or infrared (IR) sensors. A mission commander (MC) has overall responsibility for the mission.

Training and Other Qualification Requirements. Prior to 1 October 1998, NAVPERS 18068F specified only one naval enlisted classification (NEC) 8362, UAV System Operator, which included EPs, IPs, and POs. Entry into this NEC was limited to specified source NECs including Aviation Electrician's Mate, Aviation Electronics Technician, Aviation Structural Mechanic, Aviation Support Equipment Technician, Avionics Technician, and Aviation Maintenance Administration. Beginning 1 October 1998, a revision of NAVPERS 18068F became effective. The USN now uses three NECs to identify EP, IP, and PO, and source NECs have changed to include almost any aviation NEC. The USN is the only service that does not permit females in UAV operator specialties. This requirement is necessary because there is no female berthing aboard ships from which the Pioneer is employed. The following requirements are based on the 1 October 1998 revision of NAVPERS 18068F.

For UAV External Pilot (NEC 8362), candidates can enter training without having served as IP or PO but they must serve at least one term of service prior to entry. The grade requirement for entry is E-5 or greater. EP candidates must complete a 24-week training course at the Joint UAV Training Center (JUAVTC) at Ft Huachuca, AZ. For both UAV Internal Pilot (NEC 8363) and UAV Payload Operator (NEC 8364), candidates must serve at least one term of service prior to entry. For IP, the grade requirement for entry is E-5 or greater. For PO, the grade requirement for entry is E-4 or greater. PO and IP candidates must complete different 8-week training courses at the JUAVTC. The MC must be a flight officer (i.e., fixed- or rotary-wing pilot or navigator)

and satisfy all associated qualification standards. Physical qualification consists of initial and recurring requirements for EPs, IPs, POs, and MC. A Class III flight physical is required for all crewmembers except MC (USN Manual of the Medical Department, 15-65, August 1998). The Class III flight physical is similar to the air traffic controller flight physical. Health conditions relative to hypoxia or pressure changes are not disqualifying. Chronic use of any medication is considered disqualifying unless approved by waiver. Other standards include visual acuity corrected to 20-20 in each eye, normal color vision, normal hearing, speech clear and distinct, and voice well modulated. In addition, normal depth perception is required for EP. Individuals who fail depth perception testing are restricted to PO or IP positions. The MC is required to complete a Class I flight physical.

Short-Range, Tactical UAV: Pioneer (USMC)

Mission. The mission of the USMC Pioneer is to support operational maneuver from the sea by providing day-and-night NRT RSTA, BDA, and battlefield management in support of the Marine Air Ground Task Force company, battalion, or smaller unit. It has a maximum altitude of 15,000 ft, an operational radius of approximately 100 nm, and approximate endurance of 5 hours.

Crew Composition/Roles. Crew composition and roles are the same as those for the USN Pioneer. An MC has overall responsibility for the mission.

Training and Other Qualification Requirements. The USMC uses two military occupational specialties (MOSs) to identify UAV operators (USMC Military Occupational Specialty Manual, MCO P1200.75; May 1998). UAV Air Vehicle Operator, MOS 7314, identifies both IP and PO. Candidates can be graduates of basic training or enlistees from any source specialty. The minimum grade requirement for entry is E-1 or greater. Both IP and PO must successfully complete the same 8-week training course at the JUAVTC. Candidates for External UAV Operator, MOS 7316, must demonstrate satisfactory performance as an IP or PO. The minimum grade requirement for EP is E-5 or greater. EP candidates must display superior adaptation to three-dimensional spatial relationships based on observed performance in IP or PO positions and complete a 19-week training course at the JUAVTC. The MC must be an aviation officer (either fixed- or rotary-wing pilot, navigator, or electronics warfare officer) and satisfy all associated qualification and selection standards. Physical qualification consists of initial and recurring requirements for EPs, IPs, POs, and MC. Physical standards are the same as those required for USN UAV operators (USN Manual of the Medical Department 15-65, August, 1998).

Short-Range, Tactical UAV: Hunter (USA)

Mission. The mission of the Hunter is to provide short-range, day-and-night NRT RSTA, artillery fire support, BDA, and battlefield management in support of USA corps, echelons above corps, armored cavalry regiments, and divisions. It has a maximum altitude of 15,000 ft, an operational radius of approximately 145 nm, and approximate endurance of 11 hours.

Crew Composition/Roles. Enlisted flight crews operate the Hunter. The air vehicle operator (AVO) position includes both EP and IP. The EP controls the vehicle through an interface similar to RCMA flight sticks during launch/climb and descent/recovery. The IP typically monitors autopilot-controlled flight but can control the vehicle through flight sticks during ingress, loiter, mission execution, and egress. A mission payload operator (MPO) controls EO or IR sensors. A noncommissioned officer serves as MC and has overall responsibility for the mission. Typically, the MC is not the EP but has prior experience in IP or MPO positions.

Training and Other Qualification Requirements. The USA uses one enlisted MOS to identify all UAV operator positions (AR 611-21, October 1998). UAV Air Vehicle Operator (MOS 96U) includes EP, IP, PO, and MC positions. Candidates for MOS 96U must achieve an Armed Services Vocational Aptitude Battery (ASVAB) minimum standard score of 105 on the Surveillance and Communications aptitude area (i.e., scores from Arithmetic Reasoning, Auto Shop Information, Mechanical Comprehension, and Electronics Information subtests). Lateral entries into MOS 96U can come from any source specialty. The minimum grade requirement for IP and PO is E-3. There is no formally stated minimum grade requirement for EP, however, the typical grade is E-5. Satisfactory performance in IP or PO positions is a prerequisite for entry into EP training. The MC is typically an E-6. AVOs and MPOs must complete a 23-week training course at the JUAVTC. EP candidates are screened by interview and by performance assessment with a radio-controlled model airplane. If selected, EP candidates must complete a 16-week training course at the JUAVTC. Physical qualification consists of initial and recurring requirements for AVOs, MPOs, and MC (AR 611-201, October 1998). The IP and PO must pass a Class IV flight physical. The Class IV flight physical represents a lower standard than Class III and includes requirements for medium physical demands, a normal physical profile, and normal color vision. The EP must pass a Class III flight physical similar to that required for air traffic controllers.

British Army Phoenix

Mission. The mission of the Phoenix is close-range, battlefield target acquisition, reconnaissance, and surveillance. It provides day-and-night, all-weather surveillance and is designed to locate and designate targets for the Multiple Launch Rocket System (MLRS) and the 155 mm howitzer. It has a maximum altitude of approximately 8,000 ft, an operational radius of approximately 38 nm, and approximate endurance of 5 hours. Because of range and altitude, the Phoenix would fall in the category of close-range tactical UAVs but was included to represent another nation's UAV capabilities.

Crew Composition/Roles: Enlisted flight crews operate the Phoenix (Monson, Fong, Marsh, Barlett, & Howard, 1997). The flight crew consists of an air vehicle controller, imagery analyst, radio operator, and mission controller. The air vehicle controller does not fly the vehicle. After rail launch, the vehicle climbs under control of autopilot until communication links are established. The vehicle then proceeds autonomously through a programmed flight path from waypoint to waypoint (Hooton & Munson, 1992). The

Phoenix is unique among UAVs included in this research in that the vehicle can be slaved to the programmed sensor footprint. The air vehicle controller can intervene in the programmed flight through a computer screen interface but there is no joystick control of the vehicle. The man/machine interface consists of a menu of flight options that are automatically executed. The menu of flight options includes altitude, speed, heading, and maneuvers such as a figure-8 pattern, racetrack pattern, right-hand orbit, or left-hand orbit. The imagery analyst controls sensor systems. The radio operator is responsible for transferring battlefield intelligence to the Battlefield Artillery Targeting Engagement System. An enlisted mission controller interacts with tasking authorities, develops mission plans, and is responsible for the overall mission. However, British Royal Artillery is currently considering an option to include a nonpilot officer as Phoenix mission commander (G.C. Price, personal communication, 10 February 1999).

Training and Other Qualification Requirements. The selection process includes an ability test score minimum as a prerequisite for entry into technical training for all enlisted flight crew positions. The air vehicle controller is typically a corporal; the imagery analyst, a master sergeant; the radio operator, a corporal; and the mission controller, a sergeant or staff sergeant. The air vehicle controller training course is 3-weeks duration for an artillery soldier. Flight crews are not required to take flight physicals.

Medium-Altitude, Endurance UAV: Predator (USAF)

Mission. The mission of the Predator is to provide near-continuous, day-and-night, NRT RSTA in support of theater and Joint Force Commanders covering the spectrum from peace to war (Stone, 1998). It has a maximum altitude of 25,000 ft, an operational radius of 400 nm, and approximate endurance of 24 hours.

Crew Composition/Roles. An air vehicle operator (AVO) serves as internal pilot and controls the vehicle from takeoff to landing through an interface that includes computer screen, joystick, throttle, and rudder pedals. When in autonomous mode, the AVO monitors flight and during data collection often directly controls the vehicle. Typically, four AVOs are assigned to a mission--two for each shift. Generally the most senior AVO for a given shift is the mission commander. However, a nonaviation officer may serve as mission commander (e.g., intelligence officer). A sensor operator (SO) is responsible for optimal sensor selection and target acquisition. A synthetic aperture radar (SAR) operator is responsible for SAR image capture and target identification. The primary data exploitation, mission planning, and communications (DEMPC) operator identifies the target sequence and best collection method, passes the target coordinates to, and directs, the SO. A secondary DEMPC operator is responsible for image capture, annotation, and mission reporting. The crew size varies depending on the mission. The minimum crew size is three: AVO/MC, DEMPC, and SO.

Training and Other Qualification Requirements. Air Force policy requires that the AVO candidate be a pilot of a fixed-wing aircraft or a navigator holding a Federal Aviation Administration (FAA) commercial pilot's license with an instrument rating (Air

Combat Command Syllabus, RQ-1 Air Vehicle Operator Basic Training, Course RQ100BQRPN, February, 1998). Grounded pilots may also qualify but they must be world-wide deployable (Major Kevin Daily, HQ AFPC/DPAOM6, personal communication, April 4, 2000). Given that candidates for AVO can be either pilots or navigators, they would have completed undergraduate flight training. Specialized Undergraduate Pilot Training is approximately 52 weeks in duration (e.g., includes flight instruction for the T-37 in the primary phase and T-1 or T-38 in the advanced phase). Joint Undergraduate Navigator Training varies from 40 to 72 weeks depending on specialization (e.g., a longer training program is required for weapons systems officers). In addition to undergraduate flight training, candidates must complete follow-on training at Replacement Training Units (e.g., for fighter aircraft such as the F-15 or F-16) or Combat Crew Training Squadrons (e.g., for transport aircraft such as the C-130 or C-141) to achieve mission-certified status. After undergraduate flight training and follow-on training, AVO candidates must complete nine weeks of Predator basic training at the 11th Reconnaissance Squadron (RS), Indian Springs Air Force Auxiliary Field, NV. DEMPC and SOs first complete 24 weeks of initial-skills training as an Imagery Interpretation Apprentice (Air Combat Command Syllabus, *RQ-1* Sensor Operator Basic Training,Course RQ 100BQRVN, March, 1998). To enter 1N131 initial-skills training, candidates must achieve an ASVAB minimum score of 64 for the General aptitude area (i.e., scores from Arithmetic Reasoning, Word Knowledge, and Paragraph Comprehension subtests). After initial-skills training, DEMPC and SO candidates must complete nine weeks of Predator basic training at the 11th RS, Indian Springs Air Force Auxiliary Field, NV. The typical grade for DEMPC and SO is E-3. Physical qualification consists of initial and recurring requirements for AVOs, DEMPCs, and SOs. The AVO must pass a Class I flight physical. If the AVO is a medically grounded pilot, then he or she must pass a modified Class II physical and have a waiver approved for the grounding condition by the command surgeon. DEMPC and sensor operators must pass a Class III flight physical; however, visual acuity and depth perception standards are equivalent to those for Class I.

Advanced Concept Technology Demonstration

An Advanced Concept Technology Demonstration (ACTD) is a risk reduction strategy for development and acquisition of new technology. It provides a streamlined acquisition approach for rapidly demonstrating and fielding a system in limited quantity. UAV ACTDs are managed by the Defense Advanced Research Project Agency (DARPA), Unmanned Aerial Vehicle Joint Project Office. The Global Hawk is being developed as an ACTD. Development contractors for the Global Hawk are Teledyne Ryan Aeronautics (TRA) and Raytheon. The Global Hawk ACTD was in Phase II, air-worthiness testing during the period of the study. Program management was transferred to the services in Phase III. Specific training requirements are being developed in Phase III (Stone, 1998). Study information was obtained from TRA flight engineers and vehicle controllers during interviews at the Birk Flight Test Facility, Edwards AFB in July 1998.

High-Altitude, Endurance Global Hawk

Mission. The mission of the Global Hawk is to provide high-altitude, long-dwell, broad-area, deep-target surveillance and reconnaissance in support of Theater and Joint Forces Commanders covering the spectrum from peace to war (Stone, 1998). It is designed to operate at an altitude in excess of 50,000 ft with an operational radius in excess of 3,000 nm and approximate endurance of 24 hours.

Crew Composition/Roles. The ground control segment for the Global Hawk will consist of a Launch and Recovery Element (LRE) and a Mission Control Element (MCE). The LRE crew will be responsible for launching the vehicle and transferring control to the MCE for mission execution. The minimum crew in the MCE will consist of MC, command and control operator (CCO), mission planner (MP), communications operator, imagery quality control technician, and maintenance technician. During air-worthiness testing, the flight crew in the LRE consisted of a primary CCO, secondary CCO, and MP. When the system becomes operational, only a CCO and MP are expected in the LRE. At the time of the study, sensor systems had not been incorporated into the vehicle. The study was limited to the role of CCO.

In a routine situation, the Global Hawk would be completely controlled by programmed flight plans developed by the MP. The CCO would be responsible for "flight following," fault diagnosis, and mission monitoring. Although CCOs referred to tasks like "capturing" waypoints and action points (e.g., landing gear down at a particular waypoint); these tasks typically consist of monitoring programmed flight. CCO intervention would occur only in exceptional circumstances. In the case of a nonroutine situation when it would be necessary to depart from the programmed flight plan, the CCO could intervene by selecting automated flight options such as "abort," "return to base," "go to waypoint," "change heading," and "change altitude." CCOs indicated that intervention in programmed flight requires a pilot's knowledge of basic flight dynamics and knowledge of the specific flight dynamics of the Global Hawk.

Expected Qualification and Training Requirements. Preliminary requirements will be determined during Phase III of the ACTD. TRA CCOs indicated that a preliminary CCO training syllabus had been developed. In developing the syllabus, it was assumed that the incoming student would be a military pilot (fixed- or rotary-wing) or a general aviation pilot with an FAA instrument rating who is current in the air traffic control environment and has greater than 500 flight hours. Assuming prerequisite skills, an additional 200 to 250 hours of Global Hawk simulator training was recommended to gain knowledge of flight dynamics and aircraft systems. They indicated general aviation pilots with less than 500 flight hours would need significantly more flight simulator training because they would not have acquired the situational awareness needed for contingency and mission planning. CCOs emphasized the importance of being able to mentally project oneself into the aircraft to maintain situational awareness. They believed that manned aircraft flying experience had helped them develop this ability. Such awareness is required to recognize flight irregularities and to decide whether or not to override the mission plan. According to one CCO, the ideal CCO candidate would be an engineer with a pilot background.

DISCUSSION

Although information collected in this study is not suitable for statistical analysis, it is possible to note differences in qualifications and attempt to identify factors that underlie differences. Table 1 provides a summary of qualifications and special training requirements by crewmember position and UAV. In spite of efforts to include similar UAVs, comparisons of qualifications are awkward due to differences in UAV design and operation. Differences in system design have resulted in differences in the structure of flight crews. The Pioneer and Hunter are the only UAVs that require an external pilot. The Predator is the only UAV for which responsibilities of internal pilot and mission commander may be combined in a single position. In spite of such differences, meaningful comparisons can be made.

Comparisons of qualifications for mission commander reveal large differences. For the USN and USMC Pioneer, candidates for mission commander must be aviation officers. For the USAF Predator, candidates for mission commander must be officers. For the Global Hawk, subject-matter experts recommend an officer as mission commander. The USA Hunter and British Army Phoenix stand out as the only UAVs for which noncommissioned officers (NCOs) can qualify as mission commander. Service-unique adaptations underlie these differences. Interviews with USMC aviation officers serving in the role of Pioneer mission commanders provided insights into why aviation officers are required as mission commander. These officers indicated that mission commanders must fully understand the air operations environment and risks associated with UAV operations near manned aircraft. In addition, aviation officers who serve as mission commanders provide the skills and experience needed for effective mission planning and greater credibility when interacting with tasking authorities.

Although NCOs have performed successfully as mission commanders for some UAVs, a compelling argument for officers in this role relates to adaptation of new technology. Historical analyses have revealed important lessons concerning adaptation of new technology within military settings. Rosen (1991) analyzed several instances of successful and unsuccessful adaptations of new technology. These included: (a) transition from battleship to carrier aviation in the USN, (b) transition from a strategy of small wars to amphibious warfare in the USMC, and (c) transition from the use of helicopters for transport to the use of helicopters for combat assault in the USA. Results indicated that officers have a critical role in the adaptation of new technology and new operational concepts. Rosen states

> "The process of implementing an innovation has shown a persistent regularity. Senior military officers who were well respected by traditional military standards have worked to create a new set of operational tasks relevant to the new military capability and new promotion pathways for young officers to follow as they develop those new skills." (Rosen, 1991)

Officer participation is a critical requirement for the adaptation of new technology because they are in the position to influence doctrine and policy relative to the new

technology. Assuming this lesson applies today, the USN, USMC, and USAF may more quickly and effectively adapt UAV technology because for these services officers serve as UAV mission commanders.

Table 1 also presents large differences in qualifications for internal pilot. Enlisted personnel qualify for training as internal pilot for the Pioneer, Hunter, and Phoenix. Flight experience in manned aircraft is not required. Only pilots or navigators holding a commercial pilot's license with an instrument rating can qualify as internal pilot for the Predator. For the Global Hawk, experts recommended that the internal pilot (CCO) be an instrument-rated pilot and indicated that manned-aircraft flight experience was necessary for developing situational awareness. Such awareness is required in order to recognize flight irregularities and to decide whether or not to override the Global Hawk mission plan.

Hall and Tirre (1998) provided insights into reasons for USAF policy concerning Predator operator qualifications. They surveyed Predator air vehicle operators in an attempt to determine training requirements. They reported that air vehicle operators stated that training requirements prior to Predator initial qualification training are roughly equivalent to undergraduate pilot training. Furthermore, air vehicle operators believed that manned-aircraft flying experience is essential for effective employment of the Predator. Since the survey by Hall and Tirre (1998), a new factor has emerged that supports USAF policy concerning Predator air vehicle operator qualifications.

On 19 March 1999, FAA Notice 7610.71, Department of Defense Remotely Operated Aircraft Operations, implemented a change to FAA Order 7610.4, Special Military Operations, Chapter 12, Section 9, Remotely Piloted Vehicles. This notice indicates that as a result of increasing operations of remotely piloted vehicles (RPVs) outside of special use or restricted airspace, RPVs are regarded as aircraft. The notice provides guidelines for operations outside of special use airspace including communications with air traffic control authorities. Given that the notice declares UAVs to be aircraft, vehicle controller qualifications depend on UAV flight capabilities. Flight capabilities of UAVs interact with federal aviation guidelines to result in different qualifications for internal pilot.

The Pioneer and Hunter have relatively limited flight capabilities compared to the Predator and Global Hawk. The Pioneer and Hunter operate at lower altitudes (maximum of 15,000 ft) and closer to the internal pilot (100 to 145 nm) allowing flight operations and training in restricted airspace. An instrument-rated pilot is not required to serve as internal pilot for UAV flight in restricted airspace. The Predator and Global Hawk are designed for operations at extremely high altitudes (Predator: maximum altitude 25,000 ft; Global Hawk: maximum altitude in excess of 50,000 ft) and at great distances from the internal pilot (400 to 3,000 nm). According to federal airspace regulations, flight above 20,000 ft must accommodate instrument flight rules; therefore, the pilot must possess an instrument rating.

Although FAA guidelines concerning the operation of UAVs support USAF policy regarding air vehicle operator qualifications for the Predator, the argument that operator qualifications are driven by policy will not end the controversy. Enlisted personnel have served successfully as internal pilots for tactical UAVs used by other services and the possibility of using enlisted personnel as internal pilots should be explored if the USAF procures tactical UAVs. To help clarify the issues, research into the essential skills and knowledge of UAV operators is needed. One important question that should be addressed is whether manned aircraft flying skills are required for satisfactory performance as Predator air vehicle operator. The USAF Air Combat Command has commissioned research to address this question. The Air Force Research Laboratory (AFRL) at Mesa, AZ, is conducting this research (Martin, Lyon, & Schreiber, 1998).

Because UAVs are just beginning to be adapted into the U.S. military, human factors research is needed not only to help resolve the controversy over operator qualifications but also to support programs similar to those for manned aviation including physical standards, simulator training, and crew coordination training. In addition, a mission-centered approach to research is needed to develop optimum tactics, techniques, and procedures. A good example of this approach is represented by research conducted by Barnes and Maltz (1998). They examined Hunter operator performance to determine the effects of multiple factors including length of mission, day of mission, shift length, day-versus-night missions, and circadian dysrythmia. Knowledge of performance decrements associated with these factors could serve as reference points for development of remedial training or cueing technologies to minimize adverse effects on mission performance and to develop optimum tactics, techniques, and procedures.

Table 1. Summary of Qualifications and Special Training Requirements by UAV and Crewmember Position

UAV	Payload Operator	Internal Pilot	External Pilot	Mission Commander
Tactical				
USN Pioneer				
Grade	E-4	E-5	E-5	Aviation officer
Flight physical	Class III	Class III	Class III	Class I
Special training	8 weeks[a]	8 weeks[a]	24 weeks[b]	
USMC Pioneer				
Grade	E-1	E-1	E-5	Aviation Officer
Flight physical	Class III	Class III	Class III	Class I
Special training	8 weeks[c]	8 weeks[c]	19 weeks[d]	
USA Hunter				
Grade	E-3	E-3	E-5 (typical)	E-6 (typical)
Flight physical	Class IV	Class IV	Class III	Class IV
Special training	23 weeks	23 weeks	16 weeks[d]	
British Phoenix				
Grade	Corporal	NCO	NA	NCO
Flight physical	None	None	NA	None
Special training	3 weeks	3 weeks	NA	3 weeks
Endurance				
USAF Predator				
Grade	E-3	Officer, pilot or navigator[e]	NA	Officer
Flight physical	Class III	Class I or waiver	NA	
Special training	9 weeks	9 weeks	NA	
USAF Global Hawk				
Grade	tbd	Officer, pilot recommended	NA	tbd
Flight physical	tbd	Class I	NA	tbd
Special training	tbd	tbd	NA	tbd

[a]Navy payload operator and internal pilot attend different courses.
[b]Navy external pilot is not required to complete payload operator or internal pilot training.
[c]Marine Corps payload operator and internal pilot attend the same course.
[d]Marine Corps and Army external pilots are required to complete either payload operator or internal pilot training.
[e] Internal pilots for the Predator must be pilots or navigators who hold a commercial pilot's license with instrument rating.

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